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**MULTI-DIMENSIONAL TRANSFORMATION SYSTEMS  
AND DISPLAY COMMUNICATION ARCHITECTURE  
FOR MUSICAL COMPOSITIONS**

**RELATED APPLICATIONS**

This is a divisional application of Serial No. 09/039,952 filed March 16, 1998, which is a continuation-in-part of Serial No. 08/677,469, now issued as U.S. Patent No. 5,728,960.

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**FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT**

Not Applicable.

**BACKGROUND OF THE INVENTION:**

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*sub. 1*  
*13*  
The present invention relates to the field of music. More particularly, the present invention relates to a display system for displaying musical compositions, either batch or in a real time environment, and processing and communicating user performances.

Music is usually only available in the written form for one (or a fixed set of) performer/instrument types in a fixed key. Adaptations or variations of musical arrangements are complex and costly. Remotely located musicians are unable to effectively practice together. Small communities each with only a few musicians are limited to practicing with the few musicians they have.

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Performers of music have many inconveniences to deal with. One such inconvenience deals with the composing, distribution, and utilization of music display presentation, traditionally sheet music. Another major problem relates to the inconvenience of scheduling and physical gathering of multiple musicians (including instrumentalists and vocalists), which when combined in their performance provide a musical ensemble or orchestra. For example, high school band practice requires that all students be available to practice at the same time at the same place (i.e., the school music room). However, this creates difficulties in that many students have other activities which conflict with band practice which is then incomplete. Additionally, when composing, musicians often will come up with an idea when physically not with another musician.

Musicians typically work from sheet music. When composing, they write the notes down on paper that has a number of staves. If the musician transposes a composition from one key to another, the notes are also written down on the staff paper. The scores for different instruments must also be generated and written down. All of the scores are then copied for distribution to other musicians and/or music stores.

When performing, the sheet music must be found, for all parts to be played, manually distributed, manually set-up, manually handled (turn pages, etc.). There is also an unfulfilled need for quick access to a more comprehensive database of music for the performing musician, whether he is solo or part of an orchestra. Also, musicians often perform audience requests, and require access to sheet music for requested songs. Presently, there are various combinations of songs compiled in "FAKE" Books, usually by category (e.g., rock, country, blues, big band, etc.). This is only of limited help. Furthermore, the use of paper sheet music is cumbersome and inconvenient; pages often get damaged or lost, and indexed access is poor and slow.

This method of composing and distributing music is inadequate when the music is used by a band or orchestra that requires hundreds of copies. If the conductor desires the

piece to be played in a different key or certain sections of the music edited to suit the conductor's tastes, the composition must be rewritten and the new transposed copy distributed to the band or orchestra. This is a very costly, time-consuming, and laborious task if the orchestra has a large number of members.

5           Additionally, if the composition does not have a part for a certain instrument, the conductor must generate the required part from the original composition. After the score for the required instruments has been generated, the parts must be copied and distributed to the individual musicians. This, again, is a very costly and laborious task if the band has a large number of musicians requiring different parts. There is a need, therefore, for a  
10   more efficient way of transposing, editing, and distributing music scores.

          Over the past many years, great advances have been made in the electronic input, storage, and display of music. Electronic bands and orchestras are constructed using computers and MIDI equipment. Programs exist for personal computers (e.g., Apple Macintosh, DOS, and Windows machines) for an individual to use the computer for  
15   transposing music, composing music. Programs also exist for automatically inputting music from direct performance (such as directly from a keyboard, electronically through MIDI converters (such as for string instruments), via pickups and microphones, and sequencers, tone generators, etc.) To generate digital data and/or music notation.

          Musicians often perform both pre-planned and ad hoc compositions during the  
20   course of a performance. It would therefore be desirable to have the ability to access a large database of musical compositions on demand. It would also be desirable to permit communication and synchronization of a music presentation to multiple performing musicians who are playing together. It would also be desirable for a performing musician to have his or her performance of the music input onto an individual music workstation,  
25   and stored, and analyzed by an automated system, and/or communicated to one or more other networked (remote) individual music workstations..

SUMMARY OF THE INVENTION:

The present invention encompasses a musical presentation system. In one embodiment, the system enables one or more users to select a musical composition, and perform the selected musical composition at each of a plurality of individual music  
5 stands, independently capturing the performance of a respective user and communicating the individuals performance data to a master workstation (which can be standalone or one of the networked individual workstations), which combines the plurality of individual workstation performance data into a composited combined performance data and communicates said combined performance data back to all of the individual workstations  
10 wherein the individual workstations provide for audio (and/or vide and/or audiovisual) output representative of the combined performance data (which represents the musical performance inputs for all of the communicating plurality of individual workstations). The time between the users performing the segment of music and that same user hearing the audio presentation of the combined data is less than the time interval detectable by a  
15 human being. In a preferred embodiment, the plurality of individual workstations collectively provide for synchronized display presentation of a selected music composition's presentation, and provide for output of individual performance data representative of the musical performance of the user corresponding to the display presentation. Timing-synchronization is also provided for to permit synchronization of  
20 the display presentation of the plurality of individual workstations, and for synchronization by the master workstation of the plurality of individual performance data to construct the combined performance data. In one embodiment, the master workstation generates a synchronization signal that is communicated to all the individual workstations from the master workstation. Other synchronization structures are also  
25 equally acceptable, such as embedding timing synchronization data within the individual performance data.

In another embodiment of the present invention, a musical presentation system enables a user to select from one or a variety of musical compositions, control the adaptation of the selected composition, and distribute the edited version efficiently in a paperless environment. The system and process of the present invention also provides means for receiving music from a number of sources. The user selects the desired musical composition from the source. The desired composition is displayed and/or stored in the system's memory for further processing by the system prior to display and/or distribution.

In accordance with one aspect of the present invention, each of the music workstations in an intelligent music composition communication architecture provides for musical information, to be distributed for a video or visual presentation of music in a user-friendly notation, and/or provides an audio presentation that can be selectively tracked and synched to the video presentation and/or tracks and synchs the displayed video presentation to a live performance, etc.

In still another embodiment, the system includes a user input device enabling selection of the musical composition, and optionally, permitting any user specified editing desired in the composition, and, in a preferred embodiment, permitting user selection of parameters (such as the musical key in which the composition is to be played). The user can then instruct the system to transmit the newly generated music scores to one or more display subsystems (such as CRT's, LED's, LCD's, etc.), or to other systems. In the preferred embodiment, these displays take the form of liquid crystal displays built into music stand based systems, also referred to herein as display stations or workstations.

This invention also relates to a musical presentation and/or communication system, and more particularly, to a system which permits musicians to view the score or other audiovisual or visual-only presentations of a musical composition, to permit the musician/user to perform the musical composition on the instrument of choice, as selected by the user, and in the key of choice, as selected by the user.

In accordance with one aspect of the present invention, one or more music workstations are provided, consisting of a video presentation means, such as a display screen (CRT, LCD, LED, Heads Up Display (HUD) etc.) in conjunction with a computer-based system which in one embodiment stores a database of songs and music which can be utilized by the musician/user of the system.

In accordance with yet another embodiment of the present invention, there are provided numerous music workstations, such that different or similar instruments can each select a respective portion of a song to be performed, such that all musicians performing the same musical piece are provided musical presentation or representation in the same key to permit the playing of the music together. In a preferred embodiment, the system is capable of locking into a particular key (and/or instrument type) responsive to input variables (such as can be provided via an input device such as a microphone or keyboard, or voice recognition, or camera) to determine the desired key to be played in. In a preferred embodiment, the user can select an auto-transpose mode where all music is thereafter automatically transposed. The transposition can take place at a master workstation and then be communicated to the individual workstations. In one of the illustrated embodiments, the transposition of the music takes place locally at the music workstation which provides local intelligence. An original musical composition, such as selected from a stored database of a library of music is then transposed in accordance with transposition rules. Many options are available, and various transposition rules and methods are well known and documented and in use on numerous products, such as keyboards which have built-in capabilities for transposition of music, as well as computer software which provides for transposition and notation of music.

In accordance with an alternate embodiment, the user connects to a remote database via wireless or wired communication to permit downloading to the local computer of those musical pieces which the user has selected for performance. The user music terminal, or the central computer, can receive the transposed (derivative

composition) version or can receive an unmodified (original musical composition) version, which it can then display and/or convert and transpose music as necessary for each instrument and/or key.

5 In another alternate embodiment, a user can prearrange for downloading of selected compositions via a remote connection service, where the music user terminal can include a non-volatile storage memory permitting the storage and replay of all requested compositions. Alternatively, a central server can be provided, where multiple music end terminals share a single central controller computer, or each have their own computers which share in a central server computer or with each other in a distributed architecture.

10 Alternatively, a non-volatile storage structure, such as a CD-ROM, can contain a database of music which can be selected from for transposition in accordance with the present invention.

20 The present invention provides a music communication architecture and methodology that permits the synchronizing of music display presentations for multiple display stations performing the same musical composition. Bands and orchestras can be constructed using multiple independent music workstation display whether at one site or remotely distributed. In one embodiment, the music display presentations provides one or more of the display of the musical composition, performance by the user, and the output presentation for the combination of the individual performance data for a plurality of individual workstations. In one embodiment, a master workstation is responsive to the individual performance data from the plurality of individual performance data and provides means for synchronizing and compositing the individual performance data from the plurality of the individual workstations, and providing a presentation output (audio and/or video) comprising the combined virtual performance.

25 It is a further object of the present invention to permit the comparison of a performer's performance parameters, such as parameter signals obtained via a microphone and/or camera, of the performing artist's performance or execution as compared to the

stored and displayed music. The comparison includes the pitch, timing, volume, and tempo etc. of the music.(such as through audio recognition) and critique the artist's physical movements (e.g., proper finger position, etc.) through visual recognition. In a preferred embodiment, the music workstation system provides the performer and/or a conductor with a presentation performance feedback indicating the quality of the performance as compared to the stored or displayed music, such as any errors, where they occurred, etc.

It is a further object of the present invention to provide a system whereby any displayed music can be transposed (e.g., to a different key, or converted to include different or additional different instruments and voices than that in which the sheet music is originally displayed).

It is a further object of the present invention to provide automated modes of intelligent operation of the music workstations, and to provide responsiveness to multiple forms of user input.

These and other aspects and attributes of the present invention will be discussed with reference to the following drawings and accompanying specification.

#### BRIEF DESCRIPTION OF THE DRAWINGS:

FIGS. 1A and 1B show a music presentation system in accordance with the present invention;

FIGS. 2A-2G show flow charts of the processes in accordance with the present invention;

FIG. 3 shows one embodiment of the display for the music display workstations and input devices in accordance with the present invention;

FIG. 4 shows a shared music database and stand alone workstation embodiment in accordance with the present invention;



FIG. 5 shows a music communication system in accordance with the present invention;

FIG. 6 shows a master workstation and slave workstations in accordance with the present invention;

5        FIG. 7 shows an alternate embodiment of the present invention using one or more of the workstations coupled to a master controller and music database;

FIG. 8 shows a marching band environment in accordance with the present invention;

10       FIG. 9 shows a person outfitted with a sensor body suit in accordance with one aspect of the present invention;

FIG. 10 shows a movement and pattern recognition system in accordance with one aspect of the present invention;

FIG. 11A illustrates a flow chart for an alternative embodiment of the operation of the automated mode "A Mode" 240 of FIG. 2A, alternative to that illustrated in FIG. 2C;

15       FIG. 11B illustrates the process flow for an alternative overall operation relative to FIG. 2A of a music composition communication workstation in accordance with the present invention, wherein steps 200-250 of FIG. 2A are redefined to show an overall operation which also encompasses a specific networked mode A Mode 5, as further illustrated in FIG. 12;

20       FIG. 12 illustrates the process flow for the networked virtual performance mode 1150 of FIG. 11B;

FIG. 13 illustrates the process flow for automated mode 6 corresponding to process step 1153 of FIG. 11A, directed to synchronizing the display to the performance, to resynchronize the display of the music to account for performer error;

25       FIG. 14 illustrates a communications architecture in accordance with the present invention, where each of the individual music stands 1410 receives a music input 1411 and provides performance data output 1412 coupled to and communicating with a master

workstation which generates an output of virtual performance data 1451 responsive to compositing the plurality of individual performance data signals which virtual performance data 1451 is communicated back to all of the plurality of individual workstations 1410 which provide audio output responsive thereto;

5           FIG. 15 illustrates one example of data flow communication architecture for a plurality of physically separate remotely located locations, such as a teacher/master conductor/server location and each of a plurality of locations that provide communication of performance data for users of the individual workstations at each of those locations, wherein timing information is utilized by the master workstation to reconstruct and  
10          combine all of the individual performance data into a combined virtual performance data output coupled back to the plurality of individuals workstations which responsive provide audio output;

FIG. 16 illustrates a data word structure compatible with one embodiment of the present invention;

15           FIG. 17 illustrates a block diagram for a workstation (generally shown in FIGS. 5-7) and further comprising a network interface and a MIDI performance data processor;

FIG. 18 illustrates a timing diagram showing the synchronization timing of the architecture as illustrated in FIGS. 14 and 15, and data structure illustrated in FIG. 16, and showing the composited synchronized virtual performance data and the multiple  
20          individual performance data; and

FIG. 19 illustrates one example of a memory work space structure for the individual and master workstations in the virtual performance mode, in accordance with the present invention.

25          DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT:

While this invention is susceptible of embodiment in many different forms, there is shown in the drawing, and will be described herein in detail, specific embodiments

thereof with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the specific embodiments illustrated.

5 In accordance with the teachings of the present invention, a system and methodology are provided for music presentation and communication. Musical compositions can be input to the present invention from any one or more of multiple sources, such as from prestored score images, live microphone, direct input from musical instruments or vocal direct performances, scanning in of existing printed score images (optically character recognized), cameras, visuals, etc. These inputs by the system are  
10 used in the selective storage, composition, communication, and presentation of the musical system of the present invention. The system can generate additional material automatically, or permit a user to modify, communicate, display and/or reproduce the musical compositions.

15 Modification can be performed on rhythm, primary key, individual notes, chords, etc. The vast store of musical information stored in digital notation format and/or any video format, can be broadcast (analog or digital) to a local music workstation or a master controller, which can also be a local workstation. The master controller can be a stand alone unit, or act as a server as well as its own stand alone unit, or simply as a server to a plurality of other stand alone units. However, in the minimal configuration, only a single  
20 musical user station is needed.

In one preferred embodiment, the workstation is provided as a music stand where the display presentation is a liquid crystal display (LCD). The LCD that can provide monochrome, gray scale or high quality color displays, depending on design and cost constraints and desires. Other display types can also be used. A touch-screen input can  
25 provide for simplified and adaptive user input selections. An optional built-in metronome function can also be provided for display presentation audio and/or video. A

subsystem can also be optionally provided to permit the music to be audibly reproduced at the workstation through a speaker or headphone jack or other output.

It is well known in the art to convert user analog audio input into a digital format, ranging from straight Analog to Digital (e.g., A/D) conversion to processed data  
5 conversion to encoded digital music data, such as MIDI. Examples of MIDI include guitar input or other stringed instrument input through microphones or directly to MIDI-converters, or voice/non-pickup instruments through microphone converted to MIDI-input, or keyboard MIDI-input. Such input systems are commercially available from numerous companies for numerous types of interfaces at numerous interface levels.  
10 Similarly, numerous A/D converter subsystems are commercially available at chip and board solution levels (such as from Analog Devices Corporation and from Mattrox Systems).

In accordance with one aspect of the present invention, the multi-dimensional music transformation system of the present invention also enables a user to select one or  
15 more musical compositions from a larger database from a plurality of musical compositions. The database can be stored locally within the workstation, on site, or remotely stored and transmitted to the user (such as over cable, wire, telephone lines, wireless (such as radio frequencies)). The user can also optionally edit the selected score of the composition (such as changing the key and/or any note and/or timing, etc.) to suit  
20 his or her taste. The score (altered (the derivative composition) or not (the original composition)) can then be transmitted to one or more displays such as liquid crystal or CRTs in the music stands of the band or orchestra. The present invention, therefore, provides an efficient, paperless solution to communicating, presenting (displaying), and optionally one or more of transposing, editing, inputting, comparative testing-teaching,  
25 conducting, and disseminating music to one display or a large number of displays. Each display can have the same, or a different, unique, customized presentation of music notation as appropriate per selection, responsive to a set-up by a system, automatically

per predefined parameters, and/or to user input. The score can also be printed out if a hard copy is desired.

As illustrated in FIG. 1, the music is stored, such as on a large hard drive or CD ROM jukebox, in a digital format as a music library (120). The music library (120) is coupled to a processor subsystem (115). Coupling can be wireless or cabled such as through a shielded cable, fiber optic conductor, switched connection (such as via phone lines), local, or remote. The processor (115) has the local storage capacity (e.g., semi-conductor memory, disk storage, etc.) to hold the digitized version of the music composition transmitted to it on request from the library (120). The music library can be local or proximately remote from the rest of the system.

In a wireless embodiment, the music library (120) is coupled to a communications subsystem (such as a radio frequency transmitter) (125) that transmits the contents of requested compositions from the remote music library (120) to the processor (115) through the antenna (104) of the transmitter. The antenna (102) at the receiver picks up the transmitted signal and the receiver conveys it to the processor (115). This embodiment enables the music library (120) to be remote and located at a great distance from the requesting site. The communications subsystem (125) can be a transceiver for bidirectional wireless communication, or a transmitter for one-way wireless communication (such as where the requests are otherwise communicated to the music library subsystem (120), such as via a wired connection).

As illustrated in FIG. 1A, a system controller, in the form of a music stand (105C) with a liquid crystal display, is used by an operator (e.g., performer, conductor, etc.) to select one or more musical compositions. FIG. 1A illustrates two types of music workstations stands. The workstation stand (105C) provides certain optional features for a more full-featured stand, including as illustrated, speakers (140) both wireless and wired communications capability, and as illustrated, shows the processor with memory (115) as an external separate component. The music stand (105P) shows the integration

of the processor and memory into the music stand itself, and also shows both wireless (antenna (101)) and wired connection (port (107)) to permit network communication. Alternatively, the conductor stand (105C) could have all or part of the features integrated into the music stand (105C). Depending on the function for which the music workstation stand will be used, some or all of the features can be provided for that stand to minimize costs or optimize versatility. For example, in one situation, only the teacher or conductor needs the full-featured, full-powered music workstation. In that case, the performers or students do not have a full-feature workstation, but rather a scaled-down version of the workstation stand. In the preferred embodiment, a user input device (110) (such as a touch screen, microphone, keyboard, switches, voice recognition system, visual recognition system, etc.) is coupled to the processor in a wired (such as over a cable or fiber optic link) or wireless (such as over an RF link or infrared link) manner for workstation stand (105C), or directly to the processor, where it is built into the system controller as workstation (105P). The user can select an original musical composition from the touch screen of the liquid crystal display (135). The processor responds by storing that composition in the memory (115) of the local workstation of the user as requested.

Using the touch sensitive LCD (135), the user can now create a derivative musical composition. The touch sensitive LCD allows the user to enter the musical key in which the original composition will be played, edit any notes desired, and select the instruments and parts that will be playing the composition. The composition as originally composed, and the derivative or modified composition can be played back to the user over speakers (140) so that he or she may listen (e.g., such as to observe how the changes will sound) while optionally permitting simultaneous viewing of the score on the presentation visual display. Once the score has been designated (e.g., selected, edited, etc.) to the users (e.g., conductor's) taste, the appropriate portions (e.g., by musical instrument) of the scores

can then be transmitted for (optional storage and) display to the respective associated individual music workstation stands of the band members.

In a preferred embodiment, each stand has an input device (110) that permits the user of the stand to select which instrument will be using the stand. (As discussed above,  
5 this input device can take the form of a touch sensitive screen or a number of buttons or switches or voice or audio recognition, etc.)

In the preferred embodiment, each individual music workstation stand (105) can be directly and/or remotely programmed to addressably receive (and optionally to locally convert) and display the music score that is intended for the respective instrument type  
10 (user type) that will be using (is associated with) the stand. As an example, the user of the stand (or a conductor) can input their selection of saxophone into the user input device (110) of the workstation stand (105C), to program that workstation stand (105C) only to receive the musical score for the saxophone (see FIG. 3). Then, the musical scores for all selected parts can be independently broadcast to all connected workstation  
15 stands, with each individual workstation stand individually distinguishing and accepting only its part. Alternatively, each workstation stand can be individually addressed for separate broadcast reception of its own respective selected part. Additionally, the user of the stand can program the user input to select a musical part of a selected musical composition (e.g., saxophone first chair) and receive only the musical score intended for  
20 that chair. This same procedure can be followed for other instruments within the band or orchestra. Alternatively, a single music composition can be broadcast to all workstations, where each workstation has local intelligence (processing and storage) to permit local conversion for display at each workstation for the selected instrument for each workstation.

25 For wireless communications, the individual music workstation stands (105) are comprised of receivers (or transceivers where bidirectional communication is desired) and antennas (101, 103) for receiving (or transceiving) the radio frequency information from

(and to) the master workstation (such as for the conductor). The music stand also has a display (such as an LCD (135)) for displaying the musical score intended for that stand.

Referring to FIG. 1B, the music workstation stands can either be identical or broken down into conductor stands and performer stands. A conductor stand (105CON) may have more functions and control than a performer stand (105PER). A performer stand (105PER) might only have the ability to receive and display musical scores, whereas the conductor stand (105CON) has the ability to select the musical score, change the key of the musical composition, and perform other tasks only a conductor would be permitted or required to do.

In one embodiment, an RF antenna for the stand (105) can be built into the stand itself. Alternatively, instead of using RF, the performer's stand can be linked to the main (e.g., conductor's) stand using infrared, fiber optic cable, shielded cable, or other data transmission technologies. As discussed above, the communications link can be bidirectional, such as to facilitate requests and responses to facilitate the feedback of performance parameters or such that any workstation can be a master or slave, or used in combinations.

FIG. 2A illustrates the overall operation of the music composition communication workstation. It begins by starting up the system (200). The system then provides a menu (201) that allows the user to select a listing of available music compositions. The user then selects one or more compositions (210). If the user selects one from the menu that is locally stored, it directly retrieves the information. Alternatively, if it's not something locally stored, the system couples (e.g. will dial up or go through a database or network) to a remote storage site and requests and receives the selected compositions.

Any changes that are desired to the composition can be selected at the next logic block (215). If there are changes (such as to the key, or note editing, or selection of form of display or instruments), then those can be accomplished as illustrated at blocks (255) to (285).



If no changes are desired, the musical score for the composition that is selected is broadcast, transmitted, or otherwise transferred to the workstation music stand (220). It is internally stored in the local workstation music stand. Next, the score is displayed (225) on the workstation display (e.g., LCD or CRT) or a video projection system. The display can also be part of an integral stand-alone workstation or an interconnected group of components including a personal computer (such as Macintosh, or DOS or Windows PC).

The display mode selection is then made (230). This permits selection of an operational display mode, not simply choosing the resolution or color. The two main choices in the preferred embodiment are a manual mode (250) and an automated mode (240). In the automated mode selection (240), there are many sub-modes or options, such as the operational mode that permits the performer or user to do their performing without having to tend to the selection of the portion of the music to be displayed or the turning of pages. In the auto performance mode as shown on LCD (135P), there is provided the simultaneous displaying of the selected musical composition, and a display representative of the audio performance of the user, and a divergence signal or divergence data representative of analyzing the performance, preferably in approximately real-time.

FIG. 2B illustrates the manual mode (250), which provides for user manual selection of functions (252). There are many functions that the user can select, even in the manual mode, such as hitting a button or a touch screen to cause the turning of the page of the display. Another function is to go back a page or to scroll forwards or backwards. For those who are vision impaired, another function can increase the font size of the music presentation.

Thus, there are many manually selected functions that can be provided. While the manual mode can have automated functions selected, it is distinguished from the automated mode where control is partially predefined without user assistance. In the

manual mode (250), the user selects any and all features that are going to be provided (some of which can be automated). The selected function is then processed (256).

Next, any ongoing needs are processed (257). These needs can include any overlapping automated function (not otherwise inconsistent with any other selected function).

Referring to FIG. 2C, the operation of the automated mode "A Mode" (240) is illustrated. First, the user selection of the desired automatic mode is detected and responded to, illustrated as the auto-advance mode (242), the training mode (244), the performance mode (246), or any one of a number of other modes (248) as is described in further detail hereinafter. For example, auto repeat mode can be selected by designating the start and stop points, and the number of times to repeat a "looped" portion (or portions) of the displayed musical composition. Marching band mode (auto-advance based on metronome function, conductor control, etc), auto-compose mode, and many others can also be implemented. The order of selection of auto-advance, training, or performance mode is arbitrary, and the user can alternatively decide from a menu where all are simultaneously presented as choices.

The display can advance the music by page option, or by a user selection of one of many options (e.g., scrolling, tablature, video graphic tutorial display, etc.).

Referring to FIG. 2D, the automated mode 1 for auto-advance operation (242) of FIG. 2C is illustrated, where the user has selected an auto-advance performance mode. In this mode "A Mode 1" (271), the system tracks the performance by the user of the composition to the score (272). Performance refers to the actual performance by an individual person (or people) who is (are) reading the musical score upon which the performance is based. Whether that score is in tablature format, staff and clef and note notation, or some other format, the system generates appropriate signals to permit comparison of the user's performance to the musical score.

Based on a comparison, a decision is made pursuant to selection criteria programmed into the system (such as the rate at which the piece is being played, the time signature, the tempo, the rhythm, and the advancement of the music on the available display), the display presentation is advanced (274 and 278). In some cases, the music might move backwards, such as with D.S. Coda. The presentation of the display tracks the performance to permit smooth, uninterrupted playing or singing. The capability can be provided for the user to override this auto-advance, such as for practicing where it is desired to keep going back over sections. In this case, a user override option (276) is permitted to alter the automated operation. Upon cessation of user override, the system can be programmed to stop, to automatically return to the regular auto-advance mode, or to process other auto-modes (270) of FIG. 2C.

Referring to FIG. 2E, the automated mode "A Mode 2" (244) operation of FIG. 2C is illustrated corresponding to the training mode. In this mode, the system tracks the performance (280) of the individual user to the composition score, primarily for the purpose of permitting a critical analysis and comparison of the performance to the score (282). This analysis determines divergence from the selected musical score, and reveals errors or deviations from desired performance goals (e.g. match of timing of notes, duration of notes, pitch of notes, etc.), and to display those errors (284) (such as by audio or video means). Predefined performance goals provide the knowledge basis for expert system based analysis.

The system can then generate a graded score (286) indicating errors, and can present it in numerous formats such as histograms, frequency of errors, spacing of errors, etc. Identification of when the errors occur (e.g., only when going from slow to fast, or fast to slow), absolute position within the score and so forth, are also tracked and reported. Other expert system rules can be provided by music teachers which give the necessary parameters for modeling expert system reasoning, as well as guidance and suggestions on how to correct problems such as via display text, graphics, audio, etc.

The comparison of the performance to the score in the training mode is for the purpose of detecting the performer's compliance to parameters (such as the tempo, rhythm, filter, parameter, pitch, tonality, and other features that are adaptable or can be modified by performers). This parameter information is available and published in numerous forms. Thus, having provided this core set of parameters, the system can thereafter perform the training automated mode.

As illustrated in FIG. 2F, automated mode 3 "A Mode 3" is the performance mode (246). In this mode, the operation is as in automated mode 1 (auto-advance mode) except that no user override is permitted. Its primary purpose is to accompany the performer during the entire performance of a score as an automated page turner. The tracking of the "page turning" to the performance can optionally be based on inputs or criteria independent of a performer's actual performance input (e.g., microphone), such as a built-in metronome clock, a central control (e.g., a conductor or special user input), etc. Additionally, performance characteristics can be tracked, computed, and reported as in the teaching and training mode. Training feedback can optionally be provided real-time, or subsequent to completion of performance, to assist the performer as in the training mode. Alternatively, the score can be presented in a moving score mode (e.g., vertically, horizontally, or otherwise) or linear presentation as opposed to a real page turning display.

FIG. 2G shows the operation of automated mode 4 ("A Mode 4") which provides for the processing of other automated functions selected by the system. These modes can include conductor mode, karaoki mode, etc..

In conductor mode, a conductor can control communications of signals to his or her performer (such as "increase volume", or "increase tempo", or "play staccato"). Icons can be provided where the conductor simply touches a touch screen (or other input mechanisms) to supplement his hand and body motions to permit more effective communication with the performers. Alternatively, as illustrated in FIGS. 9 and 10, in a

more advanced system version, the conductor's movements are first learned by a monitoring system, based on user definition and assignment of meanings for movement to provide an expert knowledge database.

This system provides for tracking of movement input such as in FIG. 10 via video camera (1005) input of the conductor (1015) against a backdrop (e.g., blue screen) (1010) is processed by video processing unit (1020), or, as shown in FIG. 9, via body glove technology (gloves (935) or sensors (944) or sensor clothing (940) or head or eye movement tracking sensor (930) (such as used in virtual reality, flight simulation, avionics equipments (such as jets and space travel), and sports players for analyzing movement) to provide the necessary movement input. This movement input is analyzed utilizing the expert knowledge database to automatically generate a display (video and/or audio) to provide local visual and/or audio reinforcement on the local display (such as overlaying on a then unused portion of the music score display as a picture in a picture) to permit audio and video reinforcement of the conductor's body language. Thus, "a hush" body language signal that is directed towards a particular section of the orchestra would automatically be interpreted to cause the system to indicate, and only on that particular section's respective displays, a message (e.g., big face with a finger in front of it making a hush sound with a "hush" sound simultaneously output from a speaker). The conductor mode provides many benefits to performance and communication.

For all these automated modes (e.g., A Modes 1, 2, 3, 4), training feedback can be provided real time or subsequent to performance at either or both of the performer's workstation and a second (e.g., teacher's) workstation.

The advantages of electronic music composition, communication and display are many. In addition to those discussed elsewhere herein, a capability exists for expert system based artificial intelligent type assistance where the expert system assists in many of the functions performed in musical composition and performance. For example, in the Auto-Compose Mode, if the words need to be changed to match the meter, equivalent

terms can be chosen from the many sources such as thesaurus, dictionaries, rhyming dictionaries, encyclopedias, etc., to assist as well. Phrases from poetry, selected and indexed by content or topic can be re-expressed to create new works. Drum and rhythm section accompaniment can be expertly suggested, as well as harmonies, melody lines to accompany chords, chord progressions to accompany melodies, harmonies to accompany a melody, and suggested musical instrument groupings to support a particular sound, rhythm, style, tonal quality, etc.

The expert system can be built from commercially available technology, including component hardware systems with supporting software, as well as commercially available software packages which operate on commodity-type personal and business computers such as the Macintosh by Apple Computer, Windows and DOS machines based on the X86 and Pentium processor technology of Intel, technology based on the Power PC and 68XXX processor by Motorola, DEC PDP-11 technology, Sun workstations, etc. Custom microcomputer or DSP based system architecture on a chip can also be constructed, as well as ASICs, custom or semi-custom logic.

The system can be designed to take advantage of expert system design knowledge. A database of rules and facts are provided, and accumulated over time by the system in a self-learn mode. The expert system itself has the necessary logic to probe the user, monitor the performance, and apply the rules to provide feedback and reports to the user of skill level, errors, automated performance display, etc., starting with a base defined set of rules, instructions, and a knowledge database specific to music.

The form of the musical score communication can be easily shaped to fit needs. One example is MIDI (Musical Instrument Digital Interface standard) which has advantages such as of bandwidth of storage used, is widely available commercially, is standardized, etc. However, signal processing, text, icon-based, object based, and various other forms of storage, user interface, and processing can also be applied to more specific applications of product.

FIG. 3 illustrates one embodiment of an LCD display used for input control and for displaying the information from the processor and memory. In the preferred embodiment, this LCD is a touch sensitive screen enabling the functions associated with each displayed button to change, and also for the displayed buttons to be moved around the screen, depending on the function to be activated. The musical score may be edited by the conductor, such as by touching the individual note after which he is presented with a number of notes to replace the touched note. The lower portion of the screen displays instruments from which the conductor can select which instrument will be playing the composition. After a button on this screen has been touched, a number of sub-screens may come up, each with their own individual touch sensitive areas and functions to be activated by those areas. Alternatively, in addition to or instead of the touch screen, the system can provide input via separate key switches, voice recognition, etc.

As an example, if the conductor touches the transmit key on the main screen, he will be presented with a screen showing all of the instruments that he has selected for that piece and a button labeled "ALL". He may now transmit to each individual music stand or by depressing the "ALL" area, transmit to the entire orchestra.

The music library can be contained ("stored") on non-volatile storage either locally or at a remote central site containing the entire (or a subset) database of all possible music (that is then downloaded to local storage on request, either real-time at performance time or in advance.)

Alternatively, the music library can be provided on storage medium that can be easily transported and used on site locally with the presentation system. Thus, for example, disk drives, cartridges, FLASH RAM cards, plug-in memory modules, or a CD-ROM or multiple CD-ROMs in a CD-ROM changer can be used to store and contain massive data libraries on musical compositions. While this would be a more expensive route than shared use of a central library, requiring each musical group to obtain libraries on all possible compositions they may want, it has the advantage of speed, flexibility, no

need for communication with a separate remote source, and creates a whole new mass marketing area (such as for CDs or Digital Audio Tape (DATs)). Another way of utilizing this technology is to maintain a history of music used, either with the remote music library or local music library. This could be done for many reasons, including  
5 copyright royalty assessment, determining a history of musical performances and requests for future use in determining performance itineraries, etc. Alternatively, a hybrid of locally stored and centrally shared libraries can be utilized to optimize cost, speed and flexibility benefits.

In accordance with another aspect of the present invention, each display  
10 workstation can also provide the ability to convert performed musical compositions into annotated musical compositions, generating the appropriate musical notation (e.g., staff, tablature, MIDI), notes, time signature, key, instrument, or user type, etc.

The display workstation can be implemented as a totally self-contained workstation, where each workstation contains its own processing subsystem, optional  
15 communications interface (such as wireless or cable) for network use, input/output interface including one or more of a user input keypad, a speaker, a microphone, joysticks, push buttons, etc. Each of the stand alone workstations can then operate with a local database or couple to a shared music database as illustrated in FIG. 4.

The stand alone workstation(s) (105), are coupled to the shared database interface  
20 (405), and can either couple remotely (e.g., via phone lines) to the remote shared music database or to a local shared or dedicated music database (410). The shared music database (410) can either be primarily a storage means (e.g., hard disk or CD-ROM), or can include a processing subsystem (420) for local intelligence. In one embodiment, the stand alone music workstation includes the shared music database (410) and interface  
25 (405), non-volatile local storage medium for the shared databases (410), and a local processing subsystem (420), and can operate completely stand-alone. In an alternate embodiment of this stand-alone device, the shared database interface is contained in the



stand-alone workstation (but not the shared music database or processing subsystem), and provides capability for communication with a stored database (410) remote from the stand-alone device.

5 In either of these embodiments, an alternate additional embodiment provides capability for each stand-alone workstation to function as a master stand-alone, or a master or slave workstation within a workstation set including multiple stand-alone workstations, wherein one is designated master and the rest are designated slaves. The slave workstations in this configuration receive communication of music compositions to be displayed from the master workstation, thereby permitting one shared music database  
10 to be communicated among all workstations which are a part of the group. It is to be appreciated that the shared music database function can be distributed in many different ways among the workstations, or separable from and independent from the workstations. The choice is simply one of design, and the illustration herein should not be taken in a limiting manner.

15 In one embodiment, the master workstation has complete control over the slave workstation. Anything displayed on the master workstation is also displayed on the slave workstation. It is also possible for the user to mask certain portions of the display of the master workstation before it is displayed on the slave workstation. In this manner, the conductor, using the master workstation, can transmit to the slave workstations only  
20 that information that is required by the orchestra members.

In an alternate embodiment, the slave workstation communicates performance parameters or deviation signals to the master workstation, for error analysis feedback.

In accordance with another aspect of the present invention, means are provided wherein a plurality of individual workstations are coupled together in the network  
25 configuration to provide for networked communication of musical performance data wherein each of the individual music workstations provides for capturing the performance data for a users performance and communicating that performance data to a master or a

conductor workstation which synchronizes and combines the plurality of individual workstations performance data to create a composite virtual performance data output which is recommunicated back to all of the individual workstations in approximately real time, so that the individual workstations can receive the composite virtual performance data and provide an audio output (and/or visual presentation) of the combined composite virtual performance data including all of the individual workstations users performances. While the networking can be used in conjunction with other features and embodiments of the present invention, including communication of musical compositions for display, and other musical performance data analysis and data communication, as well as inter-musician interpersonal communication, the networked embodiment of the present invention permits synchronized virtual performance thereby permitting multiple remotely located individual workstations to physically separately perform with the benefit of hearing in approximately real time the combined result of all the performances at the individual workstations with their own individual performance.

In accordance with another aspect of the present invention, means are provided to permit a user of the music workstation to accomplish a transposition of a musical composition in pitch, tempo, and otherwise. In a preferred embodiment, the lead voice or instrument can audibly indicate the key via the microphone input or via another type of input stimulus. The workstation can analyze the user input, determine the key, pitch and tempo for a musical composition being partially performed by the user, and adjust and transform the composition to be displayed in the new user desired key, pitch, tempo, etc., either solely for use on that workstation, or communication for use on one or more other workstations. In a networked version, this user input can also be communicated to other workstations for use by one or more of the workstations in transposing, or communicated to a master workstation, which transposes and rebroadcasts the transposed composition.

Alternatively, the user can input the pitch, tempo, and key via the user input (e.g. keypad, joystick, push buttons, voice recognition, playing of an instrument, etc.) and the system performs the transformation and displays (and/or prints out and/or audibly performs) the modified transformed composition for the user. Additionally, where a musical composition is written for one instrument and a different or additional instrument version is desired for simultaneous performance, the user can indicate the other instruments via the user input, and the system will generate the appropriate displays. The workstation can also provide an audio output of the transformed musical composition, either for the individual additional instrument or voice transform and present it, or for the composite of additional versions and the original version, to hear the blended piece.

Referring to FIG. 5, a music communication system is illustrated comprising multiple workstations (500) each comprising a display (510), user input such as a keypad (522), a joystick (524), push buttons (525 & 526), a microphone (527), and a speaker (528). The workstation also includes communication interface means such as a wireless interface including an antenna (531), or alternatively or additionally a wired or cabled communication interface (540). Each workstation further includes a local microcomputer subsystem (550) that provides local intelligence and management of functions in the workstation.

In the networked embodiment, where multiple physically separate locations each having one or more individual workstations provide for communication of performance data from the individual workstations and presentation by the individual workstations of the combined virtual performance data at the individual workstation, to provide for a virtual performance. In this case, the communications interface would utilize slightly different structure, such as a phone modem (analog modem), a cable modem, ISDN as between locations, etc.

Communications interfaces of various types are well known and commercially available. At the present time, they are available for purchase at the chip, board, or system level. In fact, many single chip microcomputers include communications interface capabilities, wired or wireless.

5           The workstation further includes an optional musical instrument input (562) and a musical instrument output (564) that permit the coupling of a musical instrument via a musical instrument interface (570) directly to the workstation. Thus, a keyboard, electric guitar through appropriate input, or a microphone input through the interface (570) permits instruments or voices to be directly input to the workstation for direct input  
10       independent of the microphone (527).

          The instrument output permits coupling of the instrument input signal, either directly fed through or as modified by the workstation for output to the appropriate public address or amplification and presentation system or separate analysis system. The workstations are coupled either via wired or wireless communication to a processor  
15       subsystem (580) that includes a processor, non-volatile memory, read/write memory and an interface to a non-volatile storage medium (582).

          The processor subsystem (580) includes an appropriate communications interface, such as a communications interface (540) for wired interface or (532) for wireless interface including antenna (533). The processor subsystem couples to a  
20       non-volatile storage medium (582) containing, among other things, application programs, transformation programs, and either a shared music library interface application program or the actual shared music library and access program.

          As described above, the processor subsystem (580) and non-volatile storage (582) music library can be built directly into one of the music workstations (500) to be a  
25       master, with the other workstations being slaves, that can either include the processor subsystem and non-volatile storage or can be lower cost dummy slave terminals. As illustrated in FIG. 6, a first master workstation (300) provides a basic workstation

subsystem (200) plus contains the processor subsystem (280) and non-volatile storage system (285) as a part thereof so as to provide a complete stand alone music communication system, and be capable of acting as a master or master/slave. This master workstation(s) (300) can function as a stand alone, or can couple to one or more other  
5 workstations, including one or more masters (300) and/or one or more non-master workstations (105).

The multiple connected workstations can operate as stand alone workstations using their local intelligence for displaying downloaded or resident music compositions. They can also interact in a master/slave linked environment, where one of the master  
10 workstations (300) asserts a master status, and all other interconnected workstations, whether workstations (105) or master/slave workstations (300) operate in a slave mode coupled to independent on the designated master. Additionally, masters can communicate between each other for a master/master network configuration.

Alternatively, the multiple connected workstations can operate together in a  
15 networked virtual performance mode, or in a networked communications mode. A dedicated stand alone or distributed master workstation architecture can provide for the coordination and combination and synchronization of the multiple individual performance data outputs into a combined virtual performance data output.

Referring to FIG. 7, an alternate embodiment of the present invention is provided  
20 where one or more workstations (105) include, at a minimum, a display of the music notation. These workstations are coupled to a master music communications controller (415) that provides for a separate user input (411) which provides input interface, such as to a MIDI status stream, computer data links (such as RS232, modem data link) etc. that designate requested musical compositions, transformations, and display requests for  
25 various ones of the coupled workstations.

In an alternative embodiment, the master music communications controller 415 provides for additional functionality including virtual performance mode, wherein the

input interface (such as the MIDI stream, computer data links, etc.) provide one or more of musical compositions data for display, transformation information, display requests, user individual performance data, and wherein the workstations respond to the master music communications controller to couple their individual performance data and receive  
5 back the combined virtual performance data.

The workstations (105) access the music database storage means (420) that provides the data for the requested music composition via the master controller (415). The master controller (415) displays both the requested music composition as well as user interface communication for the music communication system to be displayed on  
10 either a dedicated display (416) or on one of the workstations (105) as designated by the master controller (415). The music database (420) can either be local, or can be via a data link (e.g., phone line, RF, otherwise). In one embodiment, a motion sensor subsystem (422) monitors motion of a target person and responds in accordance with predefined movement interpretation characteristics parameters, such as for a conductor.

15 In a preferred embodiment, the user input means (411) is comprised of a key switch device, such as a touch membrane keypad or capacitance touch surface. Alternatively, in one preferred embodiment, the user input is provided via a touch screen technology. Touch screen technology permits the display of user interactive icons and legends including text and graphics making possible unlimited customization of user input  
20 structure according to task needs. Thus, specific switches or sequences of touches to the touch screen can be associated with common use icons from the task being performed in conjunction with words to provide ultimate clarity. User error is virtually eliminated, with the aid of automatic entry error detection, such as defined fields, mandatory fields, etc.

25 Alternatively, the microphone input (527) can provide for coupling of user speech to a processor subsystem (580) that uses any of a number of commercially available and well known speech recognition algorithms. These algorithms provide for speech

recognition input control, either solely or as a supplement to touch screen or other tactile input mechanisms.

In a deluxe embodiment, an output (421) is provided that permits coupling of an external display, such as a color monitor, projection unit, or other display presentation system including one or more of audio, visual, and audiovisual.

Additionally, the display presentation output of the workstation can provide for an audio output presentation of the musical performance, either generated by the workstation responsive to the music composition data, to the users performance, to the combined virtual performance data, or responsive to an external source. Additionally, a visual or audio visual presentation can be provided to provide information feedback to the user on both their individual performance as well as from and between individual workstations and/or the master controller or conductor workstation.

In accordance with another aspect of the present invention, means are provided for moving through the printed (displayed) notation of the music in synchronization with the live performance from the displayed musical notation.

Musical notation is used, in the generic sense, to refer to any way of conveying musical performance instructions including but not limited to common musical notation with staves, notes, sharps, flats, and clefs, extending to written instructions in text form to supplement this or supplant or partially replace, as well as alternate forms of expression such as chord charts, words and chords (letters), tablature, any video, graphic, audio, audiovisual or other display presentation or combination of the aforementioned types of presentations.

An annoyance in performing music using any written notation (whether on paper or displayed on a presentation apparatus such as a screen) is smoothly performing music and timing "flips of pages" (or the communication of change to a third party, such as touching a key or button). This is especially true when the user is marching and both hands are required simultaneously.

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In accordance with one aspect of the present invention, means are provided to accept inputs from one or more sources that initiates a "page turn". Types of inputs include conventional touch input apparatus (such as key switches or capacitive touch pads), motion sensing gear, and automatically when operating in the operational mode of Auto Mode. The motion sensing gear can be for a portion of the performer's body, such as a head tilt sensor or an optical eye movement sensor, etc.

Additional types of inputs that can initiate a "page turn" include voice or sound recognition apparatus built into the microcontroller system. This apparatus has the ability to use pattern recognition specific to the sound or user voice and words being said (for extremely high accuracy). Of course, any type of user actuated device such as a foot or hand switch, or head motion device, or sound or voice recognition system, in a preferred embodiment, is selectively permitted to control the override of the normal progression of the music's play.

The override may cause the progression to go backwards or forwards in the music score irrespective of the normal reading of it. The performance mode AutoMode blocks the user override to permit performance according to proper material timing and either progresses responsive to the music composition data timing, or in an optional embodiment, to the performer. This automatically moves through the musical score as written and preferably shows an indication of metronome time and an indication of the proper place in the score where the performer should be for that instrument at any specific time. This is especially valuable in a conductor mode of networked communication, where a conductor couples to one or more music workstations.

The user's performance can be compared to the score, and feedback can be provided to the performer as to the quality of their performance.

In the performance monitor mode, for a single user or multiple users, the user (or a remote teacher or conductor) can indicate the rate at which he feels the performer should be performing. A microphone input on the music workstation samples the user's actual



performance and permits providing a graphical mapping (for the user or teacher/conductor) showing the relative synchronization of the performer's actual performance versus the conductor's desired performance.

In an alternate automatic advanced mode, the display of the music composition is synchronized to the performers actual performance. Thus, rather than simply indicating visually for the teacher/conductor or user what their relative performance was to the written displayed musical composition, the relative performer to written music synchronization information can be utilized to adjust the display rate of the actual musical composition to match that of the performer.

With use of appropriate sound baffling, a plurality of instruments can simultaneously be monitored and controlled by the conductor, so long as each instrument's output sound pattern is communicated directly to a respective workstation. The output of each of the workstations can then be coupled to the conductor's master workstation for further analysis and processing.

A workstation for an oboe may have a built in slide boom with a featherweight microphone to be able to receive sound input from the oboe. Electric instruments, such as guitars, keyboards, and other electrical analog signal sources can be fed directly to a line input that is appropriately buffered and filtered. Signal input can also be accommodated through a MIDI-interface subsystem that permits both utilization of data in workstation to workstation communications and utilization of MIDI-output at the station where the data was input.

For networked virtual performance, and for one aspect of output display presentation, the utilization of MIDI input and MIDI output, at each of the individual workstations and at the master controller workstation, permits the capture of the user performance and conversion to individual performance data which includes time synchronization information which can be communicated to the master workstation, which synchronizes and combines the individual performance data to generate combined

virtual performance data which is then communicated back to the individual workstations which utilizing their MIDI output interfaces provide for display presentation ( e.g. audio output) of the combined virtual performance data. Additionally, even where virtual performance mode is not selected, the provision of MIDI interface input and output on  
5 the workstations have other multiple beneficial users as discussed elsewhere herein.

Additionally, other types of user performance to user performance data input devices and transducers can be utilized, as are well known commercially available including variations of analog digital converter input devices, audio signal capture, etc.

By combining the conductor and performance mode operations, the workstation  
10 can be enhanced to provide training and comparison of performance to actual music.

Some music is only available in annotated forms where there is not an existing signal showing proper synchronization of the signals. Thus, a controller subsystem (such as (580)) provides for real time conversion and analysis of syntax of the music notation, in conjunction with a precision clock metronome, and provides an indicator (such as color  
15 or other highlighting or bolding or accentuating) of the relative timing of the performance relative to a place in the sheet music (or other form of musical notation).

Existing forms of music notation can be converted manually, or can be converted automatically by scanning in sheet music, recognizing (using optical character recognition) the various elements of the music, and facets and specifics of the syntax in the form of  
20 notation including its constants and variables and protocols, and integrating via an artificial intelligence type expert system that notates, highlights, and accentuates via synchronized metronoming of time signature to music. Any of a variety of other means of converting music can also be used, such as direct input of musical performance signals processed via software that converts it into musical notation. Such software is  
25 commercially available, such as from ARS NOVA, Wildcat Canyon Software, Mark of the Unicorn, Inc., and Passport Designs, Inc.

Since the music notation is now in computer usable form, it is now an easy task to communicate, display, compose, alter, and transpose music (such as in key, for types of instruments or voice parts, and harmonies) via well known techniques.

Additionally, where the user input is converted into user performance data for the workstation, the users individual performance data is also now in computer usable form and if appropriately converted from performance to performance data, includes appropriate synchronization data relative to master controller performance synchronization signal. Thus, both the music notation is in computer usable form (making it easy to display, alter and analyze/compare), and the users performance is in computer usable form (digital individual performance data), it is possible to provide intelligent operation and analysis and utilization of both the music composition information and the user performance information, to provide for various automated modes and features to the users

Implementation can also be in a custom design comprised of a microprocessor, non-volatile storage memory, read/write memory, and whatever additional peripheral circuitry is needed (such as are available in ASICs, or single chip microcomputer chip sets including CPUs, DSPs, A/D, and other peripheral support circuitry). These single or multiple chip solutions can be utilized to create a dedicated system to perform complete music workstations performance criteria to support an extremely low cost, high volume music workstation solution.

A new form of communication is created in that both the process of communicating via standard notation is respected and adhered to, while at the same time permitting interaction and communication of music media signals ranging from simple analog, digitized (analog to digital converted), individual performance data (representative of the user's performance), and can optionally include timing/synchronization data.

A multi CD ROM changer accommodates indexed storage of hundreds of thousands to millions of musical compositions to permit complete stand alone operation

of the user music workstation. Alternatively, an optional built-in or external modem can be provided to permit intercommunication with a remote central music database management system that permits both communication and down loading (and disconnect) for stand alone operation. Thus the workstation can stay on-line, pulling up music as  
5 needed, or can request a single or multiple pieces of musical works be provided to it, that are then downloaded from the central database manager. The user workstation then disconnects from the music database management system, and thereafter operates stand alone where all desired music is stored locally in storage (preferably non-volatile). Storage can be semiconductor, magnetic, optical or any other medium.

10 The use of virtual reality technology, including motion sensors and body gloves, permits monitoring of various other things (as shown in FIG. 9). For example, as shown in FIG. 10, a camera in conjunction with analysis logic, such as expert software, can monitor motion of role model behavior and compare performer behavior. Hand, finger, arm, leg, eye, head, body, and mouth movements can all be monitored and constructive  
15 critical feedback can be accumulated, analyzed, and fed back to the user or teacher, for performer training, or performances, or for conductor communication.

The input of monitored movement data is provided to the user workstation, permitting precise mechanics training such as finger position, the angle of striking of strings relative to the neck of a violin or guitar, or they can be used to permit the virtual  
20 performance of music by a performer using a virtual link apparatus such as a virtual reality glove and head movement detection apparatus. The user can then perform a piece with their own personalization without any musical instrument in fact.

For example, the guitar portion for a piece of music could be displayed in notation form and actually performed according to the timing of movements of the user's fingers  
25 (either actual fret positions, or only timing information). To add further reality, a mock guitar, keyboard, flute, or other instrument can be used and combined with virtual effects to provide for music performance and personalization. Thus, for entertainment purposes,

users could perform as part of a symphony orchestra playing a violin portion. If they performed out of time, they would hear their instrument's performance out of synch with the rest of the orchestra's performance.

There are numerous ways to embody the conductor movement interpretation system. As illustrated in FIGS. 9 and 10, one is utilizing the body movement detection apparatus prevalent in virtual reality, sports medicine, etc., as discussed above, to identify specific movement patterns or signal parameters associated with certain movement patterns, to initiate a display presentation, audio, video, or audiovisual to provide a presentation associated with movement of the conductor. Alternatively, other techniques can be used such as taking the video feed from a video camera or other video source (e.g. VCR) and having the conductor interpret his movements and assign them unique meanings, to create a lexicon of his movements and corresponding meaning.

For example, rapid downward movements of the hand from up to down, in a certain manner, indicate "decrease the volume." When he points at a particular section at the same time as he is doing that, he is indicating that only that orchestra section is to reduce volume. In this manner, either camera input of movements, glove sensing of movements, or other techniques (such as audio, ultrasonic, etc.) can be used to track movement to permit associated meanings to be attached or indexed to particular signal parameters or parametric signals of the meaning of the movement parameters as provided by the conductor input device. For example, in the case of the virtual reality glove, that input would be the signal output of the glove as interpreted by associated software in a processor (such as a PC or a MAC). Alternatively, for example, in the case of video camera input, it could be pattern recognition or analog signal comparison to determine the presence of certain signal patterns indicating to the system to initiate automatic communication of a conductor presentation. In so doing, the conductor is able to rapidly convey his meaning, focus it to a particular group of instruments, and be done with it. He

doesn't have to focus very long or concentrate to make sure they've gotten his signal. Instead he can focus on listening to see if they got his message.

FIG. 8 illustrates an alternate embodiment of the present invention. In this embodiment, the workstations are remote units (801-803) used by a member of a marching band. Each of the remote units (801-803) are equipped with receivers (810-812) that receive musical compositions transmitted to them. Remote units controllers (820-822) control the operation of the remote unit (801-803). The musical composition is displayed on the remote unit's displays (830-832) which displays can be an LCD multiple line display providing low cost, low power usage, and high visibility/readability, and with Auto Advance Mode, the display automatically scrolls as the music is to be performed.

Each remote unit (801-803) can be mounted on the instrument on or in place of the lyre. The remote unit's antenna (840-842) can be separate from or built into the remote unit or the lyre.

A transportable main unit (850) is used to transmit musical compositions to the remote units (801-803). The transportable main unit (850) is comprised of a controller (806) for controlling the transportable main unit (850), a music database storage medium (805) containing the data for the musical compositions to be played by the band, and a transmitter (804) for transmitting the musical compositions to the remote units (801-803). This main unit can be in the form of a suitcase or briefcase size item. The main unit can also be provided built into a van that is driven around with the band or as a small self-contained portable unit. In accordance with this embodiment, the band can play a virtually unlimited number of musical compositions without the problem of carrying the music with them in paper form. It also relieves the band members of the problems of changing music and changing pages while marching. As discussed in the above embodiments, in the performance mode, the musical score is automatically scrolled across the screen display (830-832). Additionally, a keyboard and/or microphone can be

attached to the transportable main unit allowing the conductor to send messages to the remote units via displays (830-832) or via a speaker associated with units (801-803). This allows the conductor to send instructions to the band (such as to take a certain route, or play at different volumes or speeds). With bidirectional communications and user performance feedback, the conductor can also monitor for errors.

FIG. 9 illustrates a conductor, stage hand, or other person with a sensor glove on each hand (935) and a head and eye movement monitor (930). The figure also illustrates the conductor wearing full body sensor equipment (940). Either embodiment or a combined embodiment can be used to map body movements. If only the gloves (935) or body sensors (944) are used, the movement of the glove or sensors can be captured by a video system, as illustrated in FIG. 10.

Other methods that capture motion rely on specialized sensors (944) placed on a performer's joints, such as via a sensor body suit (940). Once motion has been filmed or analyzed, a data set is produced to interpret that movement into Cartesian coordinates. These coordinates provide the spatial location of each of those markers. This information is then cleaned up and input to an animation package.

FIG. 10 illustrates a video camera (1005) and a standing conductor (1015) (or performing musician to be tracked or virtually linked to perform), with or without a blue screen (1010) behind him. The video camera (1005) feeds a video signal to the video processing system (1020) that utilizes signal processing to provide signal pattern recognition capability. The blue in the screen is filtered out in the signal processing such as by an Ultimatte process.

In one embodiment, the conductor is wearing a sensor equipped body suit (940) and gloves (935) of FIG. 9. In another embodiment, the conductor is wearing only the sensor equipped gloves (935) of FIG. 9. In still another embodiment, the conductor's movements are picked up by the video camera (1005) and processed without a sensor suit.

Simple things, like looking for the conductor's rapid hand movements, focusing on specific hand movement areas, facial and head movement, arm movements, and body language can all be programmed into the recognition knowledge base. Some of the technology for complete mapping of body movement that exists in making video games of today are illustrated in *Video Systems* magazine, page 42, October 1995, Vol. 21, No. 11, and *NEXT Generation* magazine, pages 49-54, October 1995, both incorporated herein by reference.

In any event, having now obtained knowledge related to recognition of the movements, the system can interpret them and utilize them to convey presentation information to the ensemble or orchestra or studio members, or to analyze a performer's movements, or to permit a virtual performance. One example would be a large screen television or multiple large screen televisions for viewing by the members of the viewing group. Alternatively, each music stand could provide for a picture in picture display of special movements of the conductor in areas of the display where music is not currently being played. Since the stand can have the intelligence to compare the performed music to the played music, that embodiment permits display of the message in portions of the music display area which have already been performed or are not going to be performed for some time (e.g., at least ten seconds in either direction; other criteria could alternatively be used, and can be set up for desired characteristics of the performing environment).

Voice recognition and response to conductor commentary can supplement the system. The system could record the message, interpret to whom the conductor directed the message and convey it audibly or translate it into a text or icon display as a part of the system's audiovisual presentation.

Referring to FIG. 11A, an alternative embodiment of the automated mode "A Mode" (240) of FIG. 2C is illustrated. The illustrated process for the automated Mode 240 of FIG. 11A includes process steps for the Auto Advance A Mode 1, Training A



Mode 2, Performance Mode A Mode 3 which are equivalent to the illustrated A Modes 1, 2, and 3 of FIG. 2C. However, as shown in FIG. 11A, at step 1148, the decision is made whether the conductor automated mode is selected, and if a “yes” decision, then automated Mode 4 is entered at Step 1149, and if a “no” decision, then logic goes to the  
5 networked virtual performance mode A Mode 5, as decided at decision logic step 1150, and responsive to the selection of the networked virtual performance mode, A Mode 5 (1151) is executed. If networked mode A Mode 5 is not selected, then processing proceeds to decision logic step 1152 to decide whether the synchronization of the display to the performance (Mode A 6) has been selected, and if so, then the processing proceeds  
10 at step 1153 to provide A Mode 6 functions. The automated mode processing ends at step 1154. It is to be noted that the automated modes can be cumulatively selected, so that the networked virtual performance can include any or all of the other automated modes, including A Modes 1, 2, 3, 4, 5, and 6, or other A Modes which may be provided. It should also be noted that the tracking of the performance by the user relative to the  
15 presentation of the musical composition (step 272 of FIG. 2D) provides the first part of the logic necessary for the A Mode 6 (synchronization of display to performance), as illustrated in FIG. 13 in further detail.

Referring to FIG. 11B, there is illustrated an alternative overall operation of a music composition communications system, alternative to that illustrated in FIG. 2A, showing additional automated modes including the network virtual performance mode A  
20 5. FIG. 11B illustrates an alternative control logic structure for the network selection, where the decision logic proceeds in an analogous manner to FIG. 2A. The operation starts at step 1100, and a mode is selected at step 1110. A composition is selected at 1120, and if the decision logic 1120 determines the composition has been selected, then  
25 processing proceeds at step 1130, which provides for selection of the mode. If no composition has been selected, processing proceeds back to the select composition step 1110. Once the composition has been selected, then a Mode is selected as illustrated at

step 1130, and the decision logic of select Mode 1140 determines whether the selected mode is that of (1) a display mode, in which case processing proceeds to step 220 of FIG. 2A, (2) a modified composition mode, in which case processing proceeds as from step 215 of FIG. 2A going to the yes branch, or (3) the select mode determines that the  
5 networked virtual performance mode has been selected, in which case processing proceeds to the networked mode automated Mode 5, step 1150, as illustrated in further detail in FIG. 12.

Referring to FIG. 12, there is illustrated the networked virtual performance process flow, step 1150 of FIG. 11B, in greater detail. At step 1150, the automated  
10 mode of networked virtual performance has been selected. This automated mode 5 is processed by proceeding to verify the selection of the composition. At step 1220, the user's performance is captured (e.g., by a microphone or via MIDI) and converted to individual workstation performance data. This data is then broadcast by each of the plurality of individual music stands to a designated master controller. At step 1230, the  
15 controller receives and combines the plurality user's individual performance data to generate a combined performance data representative of the synchronized and combined plurality of individual performance data. This combined performance data is then broadcast to all of the individual music workstations. At step 1240, each of the plurality of individual music workstations provides an output (e.g., audio) responsive to the  
20 combined performance data, which is representative of the combination of the plurality of users audio performances of the music composition, synchronized to the display presentation of the music composition. Timing synchronization data is provided to synchronize the plurality of individual music workstations individual performance data to one another and to the selected musical composition's display presentation, to facilitate  
25 synchronization for purposes of combination and audio playback at the individual workstations, in approximately real time, so as to provide apparent real time feedback of the individual user's performance in combination with all other individual users, played

back at each of the individual workstations. At step **1250**, analysis is done as to whether the composition is done. If so, processing completes at step **1260** and ends this automated Mode 5. Otherwise, if processing is not done, that is the musical composition is not over, then processing proceeds back to step **1220** as illustrated.

5 Referring to FIG. 13, there is illustrated automated Mode 6 corresponding to synchronizing the actual display presentation to the user's performance, providing resynchronization of the display of the music to account for the actual performer's timing, and any errors or differences. Automated Mode 6 is analogous to A Mode 1 without override, but not to A Mode 3, which auto-advances independent of the user's  
10 performance. At step **1153**, the automated modes 6 is entered. At step **1310**, analogous to step **272** in FIG. 2D, the user's performance is tracked and stored for comparison to the musical composition display presentation relative to the timing of where the performance should be. At step **1320**, the performance that has been tracked is compared to the score and deviation performance data for that performer is generated. At step  
15 **1330**, the errors are utilized to resynchronize the display presentation of the musical composition to adjust to the actual user's real time performance timing relative to the display presentation and a synchronization of the commencement of the user's performance relative to the musical composition's presentation on the display. At step **1340**, an analysis is done as to whether processing is complete (e.g. is the musical  
20 composition done?). If so, A Mode 6 ends at processing step **1350**, and either the automated modes of processing can end, or other automated modes can be checked for, and processing can begin for another selected automated mode.

Referring to FIG. 14, there is illustrated the communications architecture and system in accordance with the present invention, wherein there are a plurality of  
25 individual music workstations **1410**, each responsive to a user's performance of a musical input (**1411**) which is processed by the individual music workstation **1410** to provide a performance data output **1412** coupled for communication to a control system **1450**,

which can be a master controller or master workstation, which is coupled for receiving and processing the individual workstation performance data for the plurality of individual workstations. A communications interface **1413**, such as a modem, can provide for coupling and communication between the individual workstation **1410** and the master controller **1450**. In one embodiment, the modems **1413** are coupled via a public switched telephone network to a corresponding modem **1455** which couples to the master workstation to communicate by directionally between the individual workstations and the master workstation. Alternatively, any sort of cable, hardwired, or wireless communications interface and provided, and would work equally well when in accordance with the present invention. The master controller **1450** is responsive to the individual performance data outputs from the plurality of individual workstations to provide a combined and synchronized virtual performance data output **1451** which is coupled via the communications network to the plurality of individual workstations, which each then respectively provide an output (e.g. audio) **1415** for presentation to the user, representative of the combined performance data. An audio and/or visual presentation output **1452** can also be provided at the master workstation.

Referring to FIG. 15, there is illustrated the data flow and communication architecture for one embodiment of the present invention. A music communication system is provided that has a plurality of physically separate remotely located locations, each having one or more individual music workstations, wherein each of the individual music workstations provides for communication output of individual performance data for a user's performance of a displayed musical composition at that individual workstation. As illustrated, a master controller **1505** is coupled to the communications infrastructure **1510** at a first location. A plurality of individual music workstations **1511**, **1512**, **1513**, and **1514** are coupled to the communications infrastructure **1510** at location 1, designated performance group 1. Similarly, location 2, performance group 2, provides individual workstations **1521** and **1522** coupled to the communications infrastructure

1510, and location 3, performance 3, provides individual music workstation 1531, 1532, and 1533 coupled to the communications infrastructure 1510. The plurality of individual workstations 1511, 1514, 1421-1522 and 1531-1533, each provide individual performance data, providing multiple discrete time samples of performance data (e.g. time, segments of data), which can include synchronization information therein, which are communicated via the communication infrastructure 1510 to the controller or master workstation 1505. The resultant output (e.g. audio) from the individual workstations is the resynchronized combined performance data of the plurality of individual performance data, resynchronized for each of the time segments of output.

Referring to FIG. 16, the data word structure for one embodiment of the present invention is illustrated. The data structure for the individual user performance data is illustrated as comprising a header comprised of control information including a start of word, cyclic redundancy code (CRC) word, the performer's ID (a unique address for the individual workstation, which not only can provide an unique ID but can also provide for indication of an instrument type), and other control information for other modes of operation in addition to the virtual performance), payload data representing the actual performance data, and timing synchronization data. Any other data word structure providing for header information including control information, and payload information including performance data, and some timing synchronization scheme, whether or not part of the user performance data word will work equally well with the present invention.

FIG. 17 illustrates a networked system embodiment in block diagram form, illustrating the network interface subsystem and music data processor subsystems for one embodiment of the present invention, compatible with the architecture as described in FIGS. 1-15. FIG. 17 illustrates a single individual workstation 1710, although a plurality of individual workstations 1710 are usually involved in the networked system (analogous to the plurality of individual workstations 1410 of FIG. 14). The individual workstation 1710 provides for communication with a master workstation 1790, (analogous to the

communication architecture with the master workstation 1450 of FIG. 14). The musical performance by the user (1712) is coupled to an input interface 1715 which provides musical performance data to a musical data processor 1720, which can be a MIDI based processor, which provides the music processed performance data output to a network communications interface 1730 which outputs the individual musical performance data 1731 for coupling via the communications infrastructure to the master workstation 1790.

The master workstation 1790 processes the individual musical performance data 1731, from the plurality of individual workstations 1710, and provides an output 1791 of combined virtual performance data, wherein both the individual musical performance data and the combined virtual performance data are comprised of a plurality of discrete time segmented data samples, wherein the combined virtual performance data is synchronized within each sample time to provide for synchronized combination of the individual musical performance for that time segment.

A network interface subsystem 1735 is responsive to the combined virtual performance data to provide synchronized virtual performance data output to the music data processor 1725 (e.g. MIDI) which provides a sound output of the combined virtual performance data corresponding to the synchronized combination of the individual musical performance data from a plurality of the individual workstations 1710.

Additionally, the individual workstation 1710 provides data analysis and presentation processing 1740 which provides an output responsive to, inter alia, the combined virtual performance data to a presentation means such as an audiovisual display, or a video display or an audio output, 1745. Note that in a preferred embodiment, the multiple individual network workstations 1710 are synchronized (e.g. responsive to synchronization signal from the master workstation 1790), so that the plurality of the individual workstations simultaneously commence display presentation of the musical composition for synchronization of individual user performances. In one embodiment,

the output of the individual performance data (such as via a MIDI music processor) is comprised of timing synchronization information that is used by the master workstation to synchronize all of the musical performances representative individual musical performance data to virtually perform together in a combined and time-synchronized performance. The combined virtual performance data representing the synchronized virtual performance is then sent back (e.g. broadcast) to the individual workstations, coupled via the network communication interface 1735 back to the individual workstation's music data processor 1725, to provide audio and/or visual output corresponding thereto. Where the master workstation is for a conductor or teacher, the conductor mode or teacher mode can also be utilized in addition to the network virtual performance mod. In fact, all of the automated modes can be selectively combined, such as by providing layering of functions via software.

Referring to FIG. 18, the timing diagrams for the individual performance data and synchronized virtual performance data is illustrated, relative to signals output from the individual networked workstations  $NWS_1$ ,  $NWS_2$ ,  $NWS_N$  and a master workstation MWS. As illustrated, the master workstation MWS provides a synch signal to commence synchronization of all workstations (NWS) coupled to the system. In a preferred embodiment, the individual workstations (NWS) begin the display presentation of the musical composition (as does the master workstation) in synchronization with the synch signal from the master workstation. Responsive thereto, each of the individual workstations displays its musical composition, and the users of the workstations can perform the musical composition. Individual workstations (NWS) provide individual performance data responsive to the user's performance. As illustrated, workstation  $NWS_1$  provides performance data A and B at respective times, while in the individual workstation  $NWS_2$  provides individual performance data C & D at respective times, and independent workstation  $NWS_N$  provides individual performance data signals E & F at respective times. During the first time segment, individual performance data A, C & E are

output, respectively, from individual workstations 1, 2, and N. However, as shown in FIG. 18, the relative timing of output of the individual performance data (and receipt by the master workstation thereof) are skewed from one another in timing. The master workstation resynchronizes the individual performance data A, C, and E within each time segment, and provides an output of the recombined reconstructed and synchronized A, C, and E to provide synchronized combined virtual performance data. It is to be noted that synchronized virtual performance data A, C, E occurs within the first time segment T1, which contains both the individual performance data and the corresponding responsive synchronized virtual performance data. The maximum time delay  $T_D$  represents the acceptable worst case time that a user can tolerate between the user's performance output of corresponding individual performance data and the time until the synchronized virtual performance data corresponding to that individual performance data is received by the same individual workstation and provided as audio output. Similarly, during time slot 2, each of the individual workstations provides individual performance data B, D and F, slightly time skewed from each other, and the master workstation provides combined synchronized virtual performance data B, D, F, which is communicated back to the individual workstations to generate an audio output.

The present invention finds application in many different environments and embodiments. For example, a live practice can be held from multiple locations, while one or more musicians are editing the score and communicating the changes real time, re-performing them, etc. An orchestra can be at one location, while a singer can be at another location. Creating and editing and synchronizing music to movies scores can also be facilitated with the present invention with beneficial gains. For example, in a movie, a lot of elements are changing dynamically that need to be resynchronized. For example, a scene can be lengthened or shortened, and the soundtrack must be adjusted. A score which was created to the movie must be rewritten to accommodate the edited movie. Typically, the composer creates the score at home or at a studio. That score is sent to



the movie studio. However, the movie studio may edit the scene that music is used in, say a reduction of three seconds in the scene. The edited scene is sent back to the composer so that he can shorten his music. The process is slow, inefficient, and an impediment to the production process. By utilizing the present invention, this can be accommodated in real time, and from remote locations, and the virtual performance mode as well as the other modes of the music communication of the present system can be utilized advantageously for this application.

The present system provides an infrastructure for a music Internet. It can be applied to interactive editing of music. It can provide for special one on one mode for teaching and performance evaluation. It can facilitate adapting a music display to the performer's performance, or drive the display to a metronome and force the user's performance to be synched to the metronome timing. Music can be composed, edited, transposed, etc. easily, from any of the plurality of individual workstations or on a single standalone workstation. Multiple individual music workstations (IMW's) can communicate with one another, both with data and audio such as voice and/or music, and/or supplemental data such as video, audio, data files, control signals, applets, etc. Bands can practice at home without the disadvantage of either practicing alone or having to physically get together in a large grouping. Singers can group with other instruments and other vocalists via respective ones of a plurality of IMW's, one, two, or even the whole plurality being remotely located physically from one another (e.g., LA, NY).

There can be multiple instruments playing at a single location. There are many options regarding how IMW's are allocatable, such as. (1) on IMW (Individual Music Workstation) per location, (2) IMW per instrument type, (3) one IMW per performer (e.g. Instrument, vocal). There are also many options (1) for networked communications between the IMW's and/or between the IMW's and the Master Workstation. Modes can be selectively mixed and matched and combined, such as (1) all auto-modes enabled mode (2) virtual performance mode, full audiovisual, (3) audio link only mode, etc. There are

also many options as to modes of signal processing which can be applied to the user input to generate the individual performance data, ranging from simple analog to digital (A/D), to complex musical sound analysis algorithms (e.g. to detect characteristics such as instrument type, pitch tone, attack, decay, amplitude, voice signatures, etc.) There are  
5 also tremendous numbers/parameters of performance analysis algorithms that can be selected and which utilize the selected musical composition data (corresponding to that displayed on the IMW which is receiving the performance input for analysis) (e.g. the sound characteristics generated by the sound analysis of the user's performance, to (3) in between "(1)" and "(2)". Additionally, many kinds of data can be communicated between  
10 (1) IMW's (2) IMW's and a Master Workstation, and (3) IMW's and external communication interfaces, etc. Examples of the kinds of data include performance data, video data, processed/analyzed performance data, audio signals, data files, etc.

Referring to FIG. 19, the memory work space structure for both the individual and the master workstations, in the virtual performance mode, is illustrated. Each of the  
15 individual workstations provides for music data buffering of the outgoing live performance data, individual performance data IPDXXX, and further provides for storage of the incoming combined virtual performance data CPDXXX. This buffering is done within read-write memory within the individual IMW's. Similarly, the data structure for the memory buffer of the master workstation is illustrated, showing separate buffer storage  
20 locations for each of the plurality of individual workstations  $WS_1$  to  $WS_N$ , providing storage of associated respective individual performance data IPD A-N. In one embodiment, multiple frame buffers are provided in the IMWs, so that multiple time segments of IPD and CPD data can be stored in the buffer structure, and so that the buffer structure can support both input storage and output retrieval operations. Other  
25 data structures and buffering operations are also compatible with the present invention. The structure of the data word can be changed or adapted within its existing structure to facilitate the transfer of supplemental data is transferred from the IMWS or Master

Workstation, or between the IMW's, or between the Imws and the Master Workstation. By utilizing the illustrated or other compatible data buffer structure, timing and synchronized (with the frame buffered variety) asynchronous communication are facilitated, not only as between communication workstations, but furthermore, as to the  
5 operations internally of the IMW. With frame buffering, the individual workstation and master workstation can dump the result output to the buffer, or receive input individual performance data asynchronously and buffered, relative to the other operations of the respective workstation, The IMW can facilitate operation in one mode or in multiple modes concurrently.

10 From the foregoing, it will be observed that numerous variations and modifications may be effected without departing from the spirit and scope of the invention. It is to be understood that no limitation with respect to the specific apparatus illustrated herein is intended or should be inferred. It is, of course, intended to cover by the appended claims all such modifications as fall within the scope of the claims.